ANNEX E

Methodology for Estimating Emissions of CH_4, N_2O, and Ambient Air Pollutants from Mobile Combustion and Methodology for and Supplemental Information on Transportation-Related GHG Emissions

Estimates of CH_4 and N_2O Emissions

Greenhouse gas emissions from mobile combustion other than CO_2 are reported by transport mode (e.g., road, rail, aviation, and waterborne), vehicle type, and fuel type. The EPA does not systematically track emissions of CH_4 and N_2O; therefore, estimates of these gases were developed using a methodology similar to that outlined in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997).

Activity data were obtained from a number of U.S. government agencies and other publications. Depending on the category, these basic activity data included such information as fuel consumption, fuel deliveries, and vehicle miles traveled (VMT).

Methodology for Highway Gasoline and Diesel Vehicles

Step 1: Determine Vehicle Miles Traveled by Vehicle Type, Fuel Type, and Model Year

VMT by vehicle type were obtained from the Federal Highway Administration's (FHWA) *Highway Statistics* (FHWA 1996 through 2002). As these vehicle categories are not fuel-specific, VMT for each vehicle type was disaggregated by fuel type using fuel economy and consumption data, so that the appropriate emission factors could be applied. First, fuel economy and consumption data from FHWA's *Highway Statistics* were disaggregated by fuel type using a number of sources, including the Department of Energy's (DOE) *Transportation Energy Data Book* (DOE 1993 through 2002), FHWA's *Highway Statistics* (FHWA 1996 through 2002), EPA and DOE's *Fuel Economy 2001 Datafile* (EPA/DOE 2001), and the *Vehicle Inventory and Use Survey* (Census 2000). These data were used to distribute national VMT estimates across vehicle categories,[1] including passenger cars (0-8500 GVWR), light duty trucks (0-8500 GVWR), heavy duty vehicles (>8500 GVWR), and motorcycles.[2] For a more detailed description of vehicle types, see Technical Description of Mobile 6.2 and Guidance on Its Use for Emission Inventory Preparation Draft Report (EPA420-R-02-011).

VMT for alternative fuel and advanced technology vehicles (henceforth known simply as AFVs) were calculated separately, and the methodology is explained in the following section on AFVs. Since the VMT estimates from FHWA include total VMT in the United States, it was necessary to subtract VMT from AFVs from this total. National VMT data for gasoline and diesel highway vehicles are presented in Table E-1 and Table E-2, respectively. Total VMT for each highway category (i.e., gasoline passenger cars, light-duty gasoline trucks, heavy-duty gasoline vehicles, diesel passenger cars, light-duty diesel trucks, heavy-duty diesel vehicles, and motorcycles) were distributed across 25 model years based on the VMT distribution by vehicle age shown in Table E-7. This distribution was derived by weighting the temporally fixed age distribution of the U.S. vehicle fleet according to vehicle registrations (Table E-5) by the average annual age-specific vehicle mileage accumulation of U.S. vehicles (Table E-6). Both were obtained from EPA's MOBILE6 model (EPA 2000).

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[1] This methodology is presented in more detail in ICF Consulting (2001).

[2] GVWR is gross vehicle weight rating (i.e. vehicle weight plus weighted cargo capacity).

Step 2: Allocate VMT Data to Control Technology Type

VMT by vehicle type for each model year were distributed across various control technologies as shown in Table E-9 through Table E-12. The categories "EPA Tier 0" and "EPA Tier 1" were substituted for the early three-way catalyst and advanced three-way catalyst categories, respectively, as defined in the *Revised 1996 IPCC Guidelines*. EPA Tier 0, EPA Tier 1, and LEV actually refer to U.S. emission regulations, rather than control technologies; however, each does correspond to particular combinations of control technologies and engine design. EPA Tier 1 and its predecessor EPA Tier 0 both apply to vehicles equipped with three-way catalysts. The introduction of "early three-way catalysts," and "advanced three-way catalysts," as described in the *Revised 1996 IPCC Guidelines*, roughly correspond to the introduction of EPA Tier 0 and EPA Tier 1 regulations (EPA 1998).[3]

Control technology assignments for light and heavy-duty conventional fuel vehicles for model years 1972 (when regulations began to take effect) through 1995 were estimated in EPA (1998). Assignments for 1998 through 2001 were determined using confidential engine family sales data submitted to EPA (EPA 2002b). Vehicle classes and emission standard tiers to which each engine family was certified were taken from annual certification test results and data (EPA 2002a). This was used to determine the fraction of sales of each class of vehicle that met EPA Tier 0, EPA Tier 1, and LEV standards. Assignments for 1996 and 1997 were estimated based on the fact that EPA Tier 1 standards for light-duty vehicles were fully phased in by 1996.

Step 3: Determine CH_4 and N_2O Emission Factors by Vehicle, Fuel, and Control Technology Type

CH_4 emission factors were primarily obtained from the IPCC (IPCC/UNEP/OECD/IEA 1997), which were derived from the EPA's MOBILE5a mobile source emissions model (EPA 1997). The MOBILE5a model uses information on ambient temperature, diurnal temperature range, altitude, vehicle speeds, national vehicle registration distributions, gasoline volatility, emission control technologies, fuel composition, and the presence or absence of vehicle inspection/maintenance programs in order to produce these factors. Since MOBILE5a, many heavy-duty gasoline vehicles are now compliant with EPA Tier 1 and LEV emission standards. Methane emission factors for these vehicles were determined using emission factors from the California Air Resources Board (CARB 2000).

Emissions of N_2O have not been extensively studied and are currently not well characterized. The limited number of studies that have been performed on highway vehicle emissions of N_2O have shown that emissions are generally greater from vehicles with catalytic converter systems than those without such controls, and greater from aged than from new catalysts. These systems control tailpipe emissions of NO_x (i.e., NO and NO_2) by catalytically reducing NO_x to N_2. Sub-optimal catalyst performance, caused by as yet poorly understood factors, results in incomplete reduction and the conversion of some NO_x to N_2O rather than to N_2. Fortunately, newer vehicles with catalyst and engine designs meeting the more recent EPA Tier 1 and LEV standards have shown reduced emission rates of both NO_x and N_2O compared with earlier catalyst designs.

In order to better characterize the process by which N_2O is formed by catalytic controls and to develop a more accurate national emission estimate, the EPA's Office of Transportation and Air Quality—at its National Vehicle and Fuel Emissions Laboratory (NVFEL)—conducted a series of tests in order to measure emission rates of N_2O from used EPA Tier 1 and LEV gasoline-fueled passenger cars and light-duty trucks equipped with catalytic converters. These tests and a review of the literature were used to develop the emission factors for N_2O (EPA 1998). The following references were used in developing the N_2O emission factors for gasoline-fueled highway passenger cars presented in Table E-13:

[3] For further description, see "Definitions of Emission Control Technologies and Standards" section of this annex.

- *LEVs*. Tests performed at NVFEL (EPA 1998)[4]
- *EPA Tier 1*. Tests performed at NVFEL (EPA 1998)
- *EPA Tier 0*. Smith and Carey (1982), Barton and Simpson (1994), and one car tested at NVFEL (EPA 1998)
- *Oxidation Catalyst*. Smith and Carey (1982), Urban and Garbe (1980)
- *Non-Catalyst*. Prigent and de Soete (1989), Dasch (1992), and Urban and Garbe (1979)

Nitrous oxide emission factors for other types of gasoline-fueled vehicles—light-duty trucks, heavy-duty vehicles, and motorcycles—were estimated by adjusting the factors for gasoline passenger cars, as described above, by their relative fuel economies. This adjustment was performed using miles per gallon data derived from (DOE 1993 through 2002), (FHWA 1996 through 2002), (EPA, DOE 2001), and (Census 2000) shown in Table E-13. Data from the literature and tests performed at NVFEL support the conclusion that light-duty trucks and other vehicles have higher emission rates than passenger cars. However, the use of fuel-consumption ratios to determine emission factors is considered an estimate, with a moderate level of uncertainty.

Nitrous oxide emission factors for heavy-duty gasoline vehicles compliant with EPA Tier 1 and LEV emission standards were estimated from the ratio of NO_x emissions to N_2O emissions for EPA Tier 0 heavy-duty gasoline trucks.

The resulting N_2O emission factors employed for gasoline highway vehicles are lower than the U.S. default values presented in the *Revised 1996 IPCC Guidelines*, but are higher than the European default values, both of which were published before the more recent tests and literature review conducted by the NVFEL. The U.S. defaults in the *Guidelines* were based on three studies that tested a total of five cars using European rather than U.S. test procedures.

Nitrous oxide emission factors for diesel highway vehicles were taken from the European default values found in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997). Little data addressing N_2O emissions from U.S. diesel-fueled vehicles exists, and in general, European countries have had more experience with diesel-fueled vehicles.

Compared to regulated tailpipe emissions, relatively little data are available to estimate emission factors for N_2O. Nitrous oxide is not a regulated ambient air pollutant, and measurements of it in automobile exhaust have not been routinely collected. Further testing would be needed to reduce the uncertainty in N_2O emission factors for all classes of vehicles, using realistic driving regimes, environmental conditions, and fuels.

Step 4: Determine the Amount of CH_4 and N_2O Emitted by Vehicle, Fuel, and Control Technology Type

VMT for each highway category for each year were first converted to vehicle kilometers traveled (VKT) so that emission factors could be applied. Emissions of CH_4 and N_2O were then calculated by multiplying total VKT by vehicle, fuel, and control technology type by the emission factors developed in Step 3.

[4] LEVs are assumed to be operated using low-sulfur fuel (i.e., Indolene at 24 ppm sulfur). All other NVFEL tests were performed using a standard commercial fuel (CAAB at 285 ppm sulfur). Emission tests by NVFEL have consistently exhibited higher N_2O emission rates from higher sulfur fuels on EPA Tier 1 and LEV vehicles.

Methodology for Alternative Fuel Vehicles (AFVs)

Step 1: Determine Vehicle Miles Traveled by Vehicle and Fuel Type

VMT for alternative fuel and advanced technology vehicles were calculated from the Energy Information Administration Data Tables (EIA 2002a). Alternative Fuels include Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Ethanol, Methanol, and Electric Vehicles (battery powered). Most of the vehicles that use these fuels run an Internal Combustion Engine (ICE) powered by the alternative fuel, although many of the vehicles can run on either the alternative fuel or gasoline (or diesel), or some combination. The data obtained include vehicle fuel use and total number of vehicles in use from 1992 through 2001. Fuel economy for each vehicle type and calendar year was determined by estimating the gasoline equivalent fuel economy for each technology. Energy economy ratios (the ratio of the gasoline equivalent fuel economy of a given technology to that of conventional gasoline or diesel vehicles were taken from full fuel cycle studies done for the California Air Resources Board (Unnasch and Browning, 2000). These were used to estimate fuel economy in miles per gasoline gallon equivalent for each alternative fuel and vehicle type. Energy use per fuel type was then divided among the various weight categories and vehicle technologies that would use that fuel. Total VMT per vehicle type for each calendar year was then determined by dividing the energy usage by the fuel economy. Average vehicle VMT was then calculated by dividing total VMT per vehicle type by the number of vehicles. Average vehicle VMT for each vehicle type was checked against the Federal Highway Administration Highway Statistics Series for each calendar year (FHWA 1996 through 2002). Note that for AFVs capable of running on both/either traditional and alternative fuels, the VMT given reflects only those miles driven that were powered by the alternative fuel. Overall VMT estimates for AFVs are shown in Table E-3, while more detailed estimates of VMT are shown in Table E-4.

Step 2: Determine CH_4 and N_2O Emission Factors by Vehicle and Alternative Fuel Type

Limited data exists on N_2O and CH_4 emission factors for alternative fuel vehicles, and most of this data is for older emission control technologies. Several studies have estimated emission factors for alternative fuel vehicles, but similarly do not cover all of the various technologies and weight classes. Light-duty alternative fuel vehicle emission factors are estimated in Argonne National Laboratory's GREET 1.5 – Transportation Fuel Cycle Model (Wang 1999). In addition, Lipman and Delucchi estimate emission factors for some light and heavy-duty alternative fuel vehicles (Lipman and Delucchi 2002). The approach taken here is to calculate CH_4 emissions from actual test data and determine N_2O emissions from NO_x emissions from the same tests. Since it is likely that most alternative fuel vehicles use the same or similar catalysts to their conventional counterpart, the amount of N_2O emissions will depend upon the amount of oxides of nitrogen emissions that the engine produces. Based upon gasoline data for EPA Tier 1 cars, the tailpipe NO_x to N_2O ratio is 5.75. Lipman and Delucchi (2002) found NO_x to N_2O ratios for light-duty alternative fuel vehicles with three-way catalyst systems to vary from 3 to 5.5 for older technology.

Methane emission factors for light-duty vehicles were taken from the Auto/Oil Air Quality Improvement Research Program dataset (CRC 1997). This dataset provided CH_4 emission factors for all light-duty vehicle technologies except for LPG (propane). Light-duty propane emission factors were determined from reports on LPG-vehicle emissions from the California Air Resources Board (Brasil and McMahon, 1999) and the University of California Riverside (Norbeck, et al., 1998).

Heavy-duty emission factors for alternative fuel vehicles were determined from test data using the West Virginia University mobile dynamometer (DOE 2002a). Emission factors were determined based on the ratio of total hydrocarbon emissions to CH_4 emissions found for light-duty vehicles using the same fuel. Nitrous oxide emissions for heavy-duty engines were calculated from NO_x emission results using a NO_x to N_2O ratio of 50, which is more typical for heavy-duty engines with oxidation catalysts. These emission factors are shown in Table E-14.

Step 3: Determine the Amount of CH_4 and N_2O Emitted by Vehicle and Fuel Type

Emissions of CH_4 and N_2O were calculated by multiplying total VMT by vehicle and fuel type (Step 1) by the appropriate emission factors (Step 2).

Methodology for Non-Highway Mobile Sources

Activity data for non-highway vehicles were based on annual fuel consumption statistics by transportation mode and fuel type and are shown in Table E-8. Consumption data for distillate and residual fuel oil by ships and boats (i.e., vessel bunkering), construction equipment, and farm equipment and residual fuel use by locomotives were obtained from EIA's Fuel Oil and Kerosene Sales (1991 through 2002). In the case of ships and boats, vessel bunkering data from U.S. territories (EIA 2002c) were added to domestic consumption, and this total was reduced by the amount of fuel used for international bunkers.[5] Annual diesel consumption for Class I railroad locomotives was obtained from AAR (2001), while consumption by Class II and III railroad locomotives was provided by Benson (2002). Data on the consumption of jet fuel and aviation gasoline in aircraft were obtained from EIA (2002b), as described under Annex A: CO_2 from Fossil Fuel Combustion, and were reduced by the amount allocated to international bunker fuels. Data on the consumption of motor gasoline by ships and boats, construction equipment, and farm equipment were drawn from FHWA (1996 through 2002).

Emissions of CH_4 and N_2O from non-highway mobile sources were calculated by multiplying U.S. default emission factors in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997) by activity data for each source type (see Table E-15).

Table E-16 and Table E-17 provide complete emissions of CH_4 and N_2O emissions, respectively, for 1990 through 2001.

Estimates of NO_x, CO, and NMVOC Emissions

The emission estimates of NO_x, CO, and NMVOCs for mobile combustion were taken directly from the EPA's National Emission Inventory (NEI) Air Pollutant Emission Trends web site (EPA 2003). This EPA report provides emission estimates for these gases by sector and fuel type using a "top down" estimating procedure whereby emissions were calculated using basic activity data, such as amount of fuel delivered or miles traveled, as indicators of emissions.

Table E-18 through Table E-20 provide complete emissions estimates for 1990 through 2001.

Table E-1: Vehicle Miles Traveled for Gasoline Highway Vehicles (10^9 Miles)

Year	Passenger Cars	Light-Duty Trucks	Heavy-Duty Vehicles	Motorcycles
1990	1395.4	558.0	29.8	8.7
1991	1346.1	631.9	31.7	8.8
1992	1359.6	687.4	30.7	9.1
1993	1363.0	724.1	29.8	9.3
1994	1394.8	742.3	30.2	9.5
1995	1426.8	767.0	30.1	9.8
1996	1458.7	792.6	30.2	9.9
1997	1491.4	824.9	30.1	10.1
1998	1538.9	842.1	30.6	10.3
1999	1558.8	873.5	30.8	10.6
2000	1590.1	894.5	29.6	10.5
2001	1609.6	908.8	28.5	9.5

Source: Derived from FHWA (1996 through 2002).

[5] See International Bunker Fuels section of the Energy Chapter.

Table E-2: Vehicle Miles Traveled for Diesel Highway Vehicles (10^9 Miles)

Year	Passenger Cars	Light-Duty Trucks	Heavy-Duty Vehicles
1990	13.7	15.4	121.2
1991	12.4	16.4	122.7
1992	12.3	18.5	127.6
1993	12.1	20.4	135.1
1994	11.8	21.2	145.4
1995	11.2	21.9	153.4
1996	10.8	22.8	158.3
1997	10.8	24.6	167.0
1998	10.3	24.7	171.5
1999	9.9	26.0	178.3
2000	9.6	26.9	182.0
2001	9.1	27.3	184.5

Source: Derived from FHWA (1996 through 2002).

Table E-3: Vehicle Miles Traveled for Alternative Fuel Highway Vehicles (10^9 Miles)

Year	Passenger Cars	Light-Duty Trucks	Heavy-Duty Vehicles
1990	0.1	1.2	0.9
1991	0.1	1.1	0.9
1992	0.1	1.0	0.8
1993	0.2	1.2	1.1
1994	0.2	1.2	1.0
1995	0.3	1.1	1.0
1996	0.3	1.2	1.1
1997	0.3	1.3	1.2
1998	0.4	1.4	1.3
1999	0.4	1.6	1.3
2000	0.6	1.5	1.5
2001	0.8	1.8	1.8

Source: Derived from EIA (2002a).

Table E-4: Detailed Vehicle Miles Traveled for Alternative Fuel Highway Vehicles (10^6 Miles)

Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Light-Duty Cars	**97.4**	**110.7**	**133.8**	**194.1**	**228.7**	**253.5**	**289.9**	**348.1**	**381.4**	**447.2**	**602.6**	**763.1**
Methanol-Flex Fuel ICE	0.0	9.0	21.8	45.8	66.5	58.3	51.5	46.4	36.5	31.8	18.2	13.8
Ethanol-Flex Fuel ICE	0.0	0.1	0.1	0.3	0.4	1.0	3.8	7.2	9.8	21.2	41.3	51.6
CNG ICE	10.7	13.5	15.9	22.5	26.5	35.3	46.4	61.5	73.0	87.7	100.5	132.3
CNG Bi-fuel	23.1	27.1	34.4	50.7	60.4	84.7	108.8	148.2	171.8	207.1	234.4	310.5
LPG ICE	7.2	6.7	6.1	8.1	7.5	7.1	7.4	7.4	7.7	7.9	8.4	8.8
LPG Bi-fuel	56.4	54.3	51.0	59.8	57.8	54.7	57.7	57.7	59.5	60.4	62.7	64.0
NEVs	0.0	0.0	3.9	6.1	8.3	10.7	12.6	17.2	20.2	27.0	46.4	70.2
Electric	0.0	0.0	0.5	0.9	1.2	1.6	1.8	2.5	3.0	4.1	7.1	10.7
Electric-Gasoline Hybrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.7	101.3
Light-Duty Trucks	**1,222.6**	**1,115.3**	**980.4**	**1,238.4**	**1,183.1**	**1,138.7**	**1,204.5**	**1,308.6**	**1,394.1**	**1,492.9**	**1,646.3**	**1,816.2**
Ethanol-Flex Fuel ICE	0.0	0.2	0.3	0.8	1.4	3.2	11.8	22.4	30.8	67.4	129.9	164.5
CNG ICE	9.9	14.2	18.0	24.3	30.5	40.3	50.5	75.8	87.5	103.9	129.1	161.6
CNG Bi-fuel	22.9	27.0	30.4	39.1	48.1	60.3	75.0	139.2	164.9	195.6	227.2	284.1
LPG ICE	26.8	26.3	24.7	26.9	25.6	24.0	24.7	25.1	25.7	26.0	26.6	27.5
LPG Bi-fuel	1,162.9	1,047.7	905.9	1,145.8	1,075.6	1,008.3	1,039.3	1,041.7	1,080.0	1,092.9	1,121.4	1,160.2
Electric	0.0	0.0	1.0	1.5	2.0	2.6	3.2	4.4	5.3	7.1	12.1	18.2
Medium-Duty Trucks	**192.9**	**176.5**	**159.7**	**198.4**	**187.3**	**179.2**	**190.2**	**195.7**	**200.1**	**204.6**	**221.3**	**251.9**
CNG Bi-fuel	1.5	1.8	2.1	2.6	3.4	4.3	5.5	6.7	7.8	9.2	10.5	11.9
LPG ICE	16.4	16.2	15.6	17.2	16.6	15.6	16.8	17.3	17.8	18.1	19.6	22.4
LPG Bi-fuel	174.9	158.5	141.9	178.7	167.4	159.3	167.9	171.7	174.5	177.3	191.2	217.6
Heavy-Duty Trucks	**632.7**	**619.7**	**600.9**	**780.7**	**743.5**	**726.3**	**765.7**	**842.0**	**863.1**	**903.7**	**997.2**	**1,175.8**
Neat Methanol ICE	0.0	4.6	9.6	12.7	13.2	7.5	0.0	0.0	0.0	0.0	0.0	0.0
Neat Ethanol ICE	0.0	0.0	0.0	0.0	0.0	2.9	10.4	6.6	0.1	0.3	0.1	0.0
CNG ICE	14.2	18.2	22.9	29.6	31.6	51.2	68.6	88.4	96.5	123.8	139.2	176.4
LPG ICE	522.0	498.5	474.1	640.0	606.1	575.2	590.7	642.1	655.5	663.6	726.1	838.5
LPG Bi-fuel	96.5	98.3	93.6	94.8	88.4	83.9	89.3	96.5	98.8	100.3	114.1	136.2
LNG	0.0	0.0	0.7	3.6	4.3	5.6	6.7	8.3	12.1	15.7	17.7	24.8
Buses	**90.5**	**86.4**	**83.6**	**111.7**	**112.1**	**122.7**	**145.9**	**184.7**	**201.6**	**232.5**	**269.9**	**327.7**
Neat Methanol ICE	3.7	3.7	3.8	4.3	4.3	3.8	1.3	1.4	1.8	1.8	1.8	1.6
Neat Ethanol ICE	0.1	0.2	0.3	0.3	0.5	1.7	3.3	0.1	0.1	0.0	0.0	0.0
CNG ICE	17.1	19.3	21.5	27.2	29.7	44.3	62.4	97.0	107.5	134.9	160.3	195.2
LPG ICE	69.7	63.3	56.7	76.4	73.1	67.9	72.9	78.9	81.4	81.9	92.2	108.9
LNG	0.0	0.0	1.3	3.5	4.4	5.0	5.9	7.3	10.6	13.7	15.4	21.7
Electric	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Total VMT	**2,236.1**	**2,108.7**	**1,958.3**	**2,523.4**	**2,454.7**	**2,420.5**	**2,596.2**	**2,879.1**	**3,040.4**	**3,280.9**	**3,737.3**	**4,334.7**

Source: Derived from EIA (2002a).

Table E-5: Age Distribution by Vehicle/Fuel Type for Highway Vehicles

Vehicle Age	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC[a]
1	5.3%	5.8%	4.9%	5.3%	5.9%	4.2%	14.4%
2	7.1%	7.6%	8.9%	7.1%	7.4%	7.8%	16.8%
3	7.1%	7.5%	8.1%	7.1%	6.9%	7.2%	13.5%
4	7.1%	7.3%	7.4%	7.1%	6.4%	6.7%	10.9%
5	7.0%	7.1%	6.8%	7.0%	6.0%	6.2%	8.8%
6	7.0%	6.8%	6.2%	7.0%	5.6%	5.8%	7.0%
7	6.9%	6.5%	5.6%	6.9%	5.2%	5.3%	5.6%
8	6.8%	6.1%	5.1%	6.8%	4.8%	5.0%	4.5%
9	6.6%	5.7%	4.7%	6.6%	4.5%	4.6%	3.6%
10	6.3%	5.2%	4.3%	6.3%	4.2%	4.3%	2.9%
11	5.9%	4.7%	3.9%	5.9%	3.9%	4.0%	2.3%
12	5.4%	4.2%	3.6%	5.4%	3.6%	3.7%	9.7%
13	4.6%	3.6%	3.3%	4.6%	3.4%	3.4%	-
14	3.6%	3.1%	3.0%	3.6%	3.2%	3.2%	-
15	2.9%	2.6%	2.7%	2.9%	2.9%	2.9%	-
16	2.3%	2.2%	2.5%	2.3%	2.7%	2.7%	-

17	1.8%	1.8%	2.3%	1.8%	2.5%	2.5%	-
18	1.4%	1.4%	2.1%	1.4%	2.4%	2.4%	-
19	1.1%	1.2%	1.9%	1.1%	2.2%	2.2%	-
20	0.9%	1.1%	1.7%	0.9%	2.1%	2.0%	-
21	0.7%	1.1%	1.6%	0.7%	1.9%	1.9%	-
22	0.6%	1.0%	1.5%	0.6%	1.8%	1.8%	-
23	0.4%	1.0%	1.3%	0.4%	1.7%	1.6%	-
24	0.4%	0.9%	1.2%	0.4%	1.6%	1.5%	-
25+	1.0%	4.6%	5.4%	1.0%	7.3%	7.2%	-
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: EPA (2000).

[a] Because of a lack of data, all motorcycles over 12 years old are considered to have the same emissions and travel characteristics, and therefore are aggregated together.

Table E-6: Annual Age-specific Vehicle Mileage Accumulation of U.S. Vehicles (Miles)

Vehicle Age	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC[a]
1	14,910	19,906	20,218	14,910	26,371	28,787	4,786
2	14,174	18,707	18,935	14,174	24,137	26,304	4,475
3	13,475	17,559	17,100	13,475	22,095	24,038	4,164
4	12,810	16,462	16,611	12,810	20,228	21,968	3,853
5	12,178	15,413	15,560	12,178	18,521	20,078	3,543
6	11,577	14,411	14,576	11,577	16,960	18,351	3,232
7	11,006	13,454	13,655	11,006	15,533	16,775	2,921
8	10,463	12,541	12,793	10,463	14,227	15,334	2,611
9	9,947	11,671	11,987	9,947	13,032	14,019	2,300
10	9,456	10,843	11,231	9,456	11,939	12,817	1,989
11	8,989	10,055	10,524	8,989	10,939	11,719	1,678
12	8,546	9,306	9,863	8,546	10,024	10,716	1,368
13	8,124	8,597	9,243	8,124	9,186	9,799	-
14	7,723	7,925	8,662	7,723	8,420	8,962	-
15	7,342	7,290	8,028	7,342	7,718	8,196	-
16	6,980	6,690	7,610	6,980	7,075	7,497	-
17	6,636	6,127	7,133	6,636	6,487	6,857	-
18	6,308	5,598	6,687	6,308	5,948	6,273	-
19	5,997	5,103	6,269	5,997	5,454	5,739	-
20	5,701	4,642	5,877	5,701	5,002	5,250	-
21	5,420	4,214	5,510	5,420	4,588	4,804	-
22	5,152	3,818	5,166	5,152	4,209	4,396	-
23	4,898	3,455	4,844	4,898	3,861	4,023	-
24	4,656	3,123	4,542	4,656	3,542	3,681	-
25	4,427	2,822	4,259	4,427	3,250	3,369	-

Source: EPA (2000).

[a] Because of a lack of data, all motorcycles over 12 years old are considered to have the same emissions and travel characteristics, and therefore are aggregated together.

Table E-7: VMT Distribution by Vehicle Age and Vehicle/Fuel Type

Vehicle Age	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
1	7.51%	9.41%	7.89%	7.51%	11.50%	8.27%	19.39%
2	9.52%	11.56%	13.48%	9.52%	13.07%	14.00%	21.15%
3	9.05%	10.62%	11.11%	9.05%	11.15%	11.86%	15.82%
4	8.59%	9.70%	9.85%	8.59%	9.51%	10.05%	11.82%
5	8.14%	8.80%	8.43%	8.14%	8.11%	8.52%	8.77%
6	7.68%	7.92%	7.21%	7.68%	6.92%	7.22%	6.37%

7	7.22%	7.04%	6.16%	7.22%	5.90%	6.13%	4.60%
8	6.72%	6.19%	5.27%	6.72%	5.04%	5.20%	3.31%
9	6.20%	5.36%	4.51%	6.20%	4.30%	4.41%	2.33%
10	5.64%	4.57%	3.86%	5.64%	3.67%	3.74%	1.62%
11	5.03%	3.82%	3.31%	5.03%	3.13%	3.18%	1.09%
12	4.38%	3.14%	2.83%	4.38%	2.67%	2.70%	3.73%
13	3.54%	2.52%	2.42%	3.54%	2.28%	2.29%	-
14	2.67%	1.99%	2.07%	2.67%	1.95%	1.94%	-
15	2.01%	1.54%	1.76%	2.01%	1.66%	1.65%	-
16	1.52%	1.16%	1.52%	1.52%	1.42%	1.40%	-
17	1.14%	0.87%	1.30%	1.14%	1.21%	1.19%	-
18	0.86%	0.64%	1.12%	0.86%	1.04%	1.01%	-
19	0.65%	0.50%	0.96%	0.65%	0.89%	0.86%	-
20	0.49%	0.43%	0.82%	0.49%	0.76%	0.73%	-
21	0.37%	0.37%	0.70%	0.37%	0.65%	0.62%	-
22	0.28%	0.32%	0.60%	0.28%	0.55%	0.53%	-
23	0.21%	0.27%	0.52%	0.21%	0.47%	0.45%	-
24	0.16%	0.23%	0.44%	0.16%	0.40%	0.38%	-
25	0.43%	1.04%	1.85%	0.43%	1.75%	1.65%	-
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Note: Estimated by weighting data in Table E-3 by data in Table E-4.

Table E-8: Fuel Consumption for Non-Highway Vehicles by Fuel Type (thousand gallons)

Vehicle Type/ Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aircraft												
Gasoline[a]	374,216	347,126	341,582	319,449	317,307	329,319	310,797	330,285	295,345	325,913	301,893	290,679
Jet Fuel	18,280,476	17,511,325	17,281,747	17,421,016	18,270,976	17,806,704	18,746,820	18,603,881	19,063,120	19,432,004	20,355,053	19,162,649
Ships and Boats												
Diesel	1,697,600	1,693,361	1,706,144	1,546,311	1,630,093	1,518,608	1,839,335	1,801,798	1,597,011	1,863,606	1,858,210	1,996,202
Gasoline	1,300,400	1,709,700	1,316,170	873,687	896,700	1,060,394	993,671	987,193	956,232	1,098,137	1,124,269	1,095,153
Residual	1,521,437	1,486,167	2,347,065	2,758,924	2,499,868	2,994,693	2,286,350	1,011,487	723,766	2,391,248	3,289,908	897,957
Construction Equipment												
Diesel	1,581,500	1,492,000	1,514,205	1,526,043	1,531,300	1,472,827	1,645,647	1,678,482	1,749,317	1,723,597	1,899,837	2,086,388
Gasoline	318,200	287,200	272,900	245,299	272,852	280,046	283,911	300,491	234,705	177,758	191,516	506,682
Agricultural Equipment												
Diesel	3,164,200	3,144,200	3,274,811	3,077,122	3,062,436	3,093,224	3,225,029	3,206,359	2,965,006	2,805,157	3,079,664	3,350,683
Gasoline	812,800	776,200	805,500	845,320	911,996	926,732	918,085	984,450	906,941	702,700	652,256	801,552
Locomotives												
Diesel	3,324,446	3,115,970	3,212,108	3,301,981	3,585,802	3,733,096	3,820,649	3,812,793	3,859,341	3,989,428	3,960,107	3,969,985
Residual	25	7	8	4	6	6	9	3	3	4	6	3
Other[b]												
Diesel	926,800	955,400	773,437	797,140	905,842	800,335	741,326	706,754	682,865	685,634	610,078	740,341
Gasoline	1,205,400	1,097,700	1,219,300	1,025,088	1,039,310	1,071,597	1,081,640	1,097,258	1,139,229	1,021,836	1,040,138	1,755,320

Sources: AAR (2001), EIA (2002b), EIA (1991 through 2002), FHWA (1996 through 2002), and other sources.

- Not applicable

[a] For aircraft, this is aviation gasoline. For all other categories, this is motor gasoline.

[b] Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Table E-9: Control Technology Assignments for Gasoline Passenger Cars (Percent of VMT)

Model Years	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV
1973-1974	100%	-	-	-	-
1975	20%	80%	-	-	-
1976-1977	15%	85%	-	-	-
1978-1979	10%	90%	-	-	-
1980	5%	88%	7%	-	-
1981	-	15%	85%	-	-
1982	-	14%	86%	-	-
1983	-	12%	88%	-	-
1984-1993	-	-	100%	-	-
1994	-	-	60%	40%	-
1995	-	-	20%	80%	-
1996	-	-	1%	97%	2%
1997	-	-	0.5%	96.5%	3%
1998	-	-	0.01%	87%	13%
1999	-	-	0.01%	67%	33%
2000	-	-	-	44%	56%
2001	-	-	-	3%	97%

Sources: EPA (1998), EPA (2002a), and EPA (2002b)
Detailed descriptions of emissions control technologies are provided at the end of this annex.
- Not applicable

Table E-10: Control Technology Assignments for Gasoline Light-Duty Trucks (Percent of VMT)

Model Years	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV
1973-1974	100%	-	-	-	-
1975	30%	70%	-	-	-
1976	20%	80%	-	-	-
1977-1978	25%	75%	-	-	-
1979-1980	20%	80%	-	-	-
1981	-	95%	5%	-	-
1982	-	90%	10%	-	-
1983	-	80%	20%	-	-
1984	-	70%	30%	-	-
1985	-	60%	40%	-	-
1986	-	50%	50%	-	-
1987-1993	-	5%	95%	-	-
1994	-	-	60%	40%	-
1995	-	-	20%	80%	-
1996	-	-	-	100%	-
1997	-	-	-	100%	-
1998	-	-	-	80%	20%
1999	-	-	-	57%	43%
2000	-	-	-	65%	35%
2001	-	-	-	1%	99%

Sources: EPA (1998), EPA (2002a), and EPA (2002b)
Detailed descriptions of emissions control technologies are provided at the end of this annex.
- Not applicable.

Table E-11: Control Technology Assignments for Gasoline Heavy-Duty Vehicles (Percent of VMT)

Model Years	Uncontrolled	Non-catalyst	Oxidation	EPA Tier 0	EPA Tier 1	LEV
≤1981	100%	-	-	-	-	-

1982-1984	95%	-	5%	-	-	-
1985-1986	-	95%	5%	-	-	-
1987	-	70%	15%	15%	-	-
1988-1989	-	60%	25%	15%	-	-
1990-1995	-	45%	30%	25%	-	-
1996	-	-	25%	10%	65%	-
1997	-	-	10%	5%	85%	-
1998	-	-	-	-	96%	4%
1999	-	-	-	-	78%	22%
2000	-	-	-	-	54%	46%
2001	-	-	-	-	64%	36%

Sources: EPA (1998), EPA (2002a), and EPA (2002b)
Detailed descriptions of emissions control technologies are provided at the end of this annex.
- Not applicable

Table E-12: Control Technology Assignments for Diesel Highway and Motorcycle VMT

Vehicle Type/Control Technology	Model Years
Diesel Passenger Cars and Light-Duty Trucks	
Uncontrolled	1966-1982
Moderate control	1983-1995
Advanced control	1996-2001
Heavy-Duty Diesel Vehicles	
Uncontrolled	1966-1972
Moderate control	1983-1995
Advanced control	1996-2001
Motorcycles	
Uncontrolled	1966-1995
Non-catalyst controls	1996-2001

Source: EPA (1998)
Detailed descriptions of emissions control technologies are provided at the end of this annex.

Table E-13: Emission Factors for CH_4 and N_2O for Highway Vehicles

Vehicle Type/Control Technology	N_2O (g/mi)	CH_4 (g/mi)	N_2O (g/km)	CH_4 (g/km)
Gasoline Passenger Cars				
Low Emission Vehicles	0.0283	0.0402	0.0176	0.025
EPA Tier 1[a]	0.0463	0.0483	0.0288	0.030
EPA Tier 0[a]	0.0816	0.0644	0.0507	0.040
Oxidation Catalyst	0.0518	0.1126	0.0322	0.070
Non-Catalyst	0.0166	0.1931	0.0103	0.120
Uncontrolled	0.0166	0.2173	0.0103	0.135
Gasoline Light-Duty Trucks				
Low Emission Vehicles	0.0354	0.0483	0.0220	0.030
EPA Tier 1[a]	0.0581	0.0563	0.0361	0.035
EPA Tier 0[a]	0.1022	0.1126	0.0635	0.070
Oxidation Catalyst	0.0649	0.1448	0.0403	0.090
Non-Catalyst	0.0208	0.2253	0.0129	0.140
Uncontrolled	0.0208	0.2173	0.0129	0.135
Gasoline Heavy-Duty Vehicles				
Low Emission Vehicles	0.1133	0.0708	0.0704	0.044
EPA Tier 1[a]	0.1394	0.0966	0.0866	0.060
EPA Tier 0[a]	0.1746	0.1207	0.1085	0.075
Oxidation Catalyst[b]	0.1109	0.1448	0.0689	0.090
Non-Catalyst Control	0.0354	0.2012	0.0220	0.125

Uncontrolled	0.0354	0.4345	0.0220	0.270
Diesel Passenger Cars				
Advanced	0.0161	0.0161	0.0100	0.010
Moderate	0.0161	0.0161	0.0100	0.010
Uncontrolled	0.0161	0.0161	0.0100	0.010
Diesel Light-Duty Trucks				
Advanced	0.0322	0.0161	0.0200	0.010
Moderate	0.0322	0.0161	0.0200	0.010
Uncontrolled	0.0322	0.0161	0.0200	0.010
Diesel Heavy-Duty Vehicles				
Advanced	0.0483	0.0644	0.0300	0.040
Moderate	0.0483	0.0805	0.0300	0.050
Uncontrolled	0.0483	0.0966	0.0300	0.060
Motorcycles				
Non-Catalyst Control	0.0071	0.2092	0.0044	0.130
Uncontrolled	0.0071	0.4184	0.0044	0.260

Sources: IPCC/UNEP/OECD/IEA (1997), EPA (1998)

[a] The categories "EPA Tier 0" and "EPA Tier 1" were substituted for the early three-way catalyst and advanced three-way catalyst categories, respectively, as defined in the Revised 1996 IPCC Guidelines. Detailed descriptions of emissions control technologies are provided at the end of this annex.

[b] The methane emission factor was assumed based on the oxidation catalyst value for gasoline light-duty trucks.

Table E-14: Emission Factors for CH_4 and N_2O for Alternative Fuel/Vehicle Technology Highway Vehicles

Vehicle Type/Control Technology	N_2O (g/mi)	CH_4 (g/mi)	N_2O (g/km)	CH_4 (g/km)
Light-duty Vehicles				
Methanol	0.063	0.014	0.039	0.009
CNG	0.113	0.914	0.070	0.568
LPG	0.152	0.609	0.094	0.378
Ethanol	0.076	0.043	0.047	0.027
Heavy-duty Vehicles				
Methanol	0.217	0.646	0.135	0.401
CNG	0.297	9.629	0.185	5.983
LNG	0.440	6.857	0.274	4.261
LPG	0.150	0.108	0.093	0.067
Ethanol	0.307	1.975	0.191	1.227
Buses				
Methanol	0.217	0.646	0.135	0.401
CNG	0.162	12.416	0.101	7.715
Ethanol	0.364	2.079	0.226	1.292

Source: Developed from Wang (1999), Lipman and Delucchi (2002), CRC (1997), Brasil and McMahon (1999), Norbeck, et al (1998), and DOE (2002a).

Table E-15: Emission Factors for CH_4 and N_2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel)

Vehicle Type/Fuel Type	N_2O	CH_4
Ships and Boats		
Residual	0.08	0.230
Distillate	0.08	0.230
Gasoline	0.08	0.230
Locomotives		
Residual	0.08	0.250
Diesel	0.08	0.250
Agricultural Equipment		

Gas	0.08	0.450
Diesel	0.08	0.450
Construction		
Gas	0.08	0.180
Diesel	0.08	0.180
Other Non-Highway		
Gas Snowmobile	0.08	0.180
Gas Small Utility	0.08	0.180
Gas HD Utility	0.08	0.180
Diesel HD Utility	0.08	0.180
Aircraft		
Jet Fuel	0.10	0.087
Aviation Gasoline	0.04	2.640

Source: IPCC/UNEP/OECD/IEA (1997).

Table E-16: CH_4 Emissions from Mobile Combustion (Tg CO_2 Eq.)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline Highway	**4.3**	**4.2**	**4.2**	**4.2**	**4.2**	**4.1**	**4.0**	**3.9**	**3.8**	**3.7**	**3.6**	**3.4**
Passenger Cars	2.4	2.2	2.2	2.1	2.1	2.0	2.0	2.0	2.0	1.9	1.9	1.8
Light-Duty Trucks	1.6	1.7	1.8	1.9	1.9	1.8	1.8	1.7	1.6	1.6	1.5	1.5
Heavy-Duty Vehicles	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Motorcycles	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	+
Diesel Highway	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Passenger Cars	+	+	+	+	+	+	+	+	+	+	+	+
Light-Duty Trucks	+	+	+	+	+	+	+	+	+	+	+	+
Heavy-Duty Vehicles	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Alternative Fuel Highway	+	+	+	+	+	+	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Non-Highway	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.5**	**0.5**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**
Ships and Boats	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Locomotives	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Agricultural Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction Equipment	+	+	+	+	+	+	+	+	+	+	+	+
Aircraft	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1
Other*	+	+	+	+	+	+	+	+	+	+	+	+
Total	**5.0**	**4.9**	**5.0**	**4.9**	**4.9**	**4.9**	**4.8**	**4.7**	**4.6**	**4.5**	**4.4**	**4.3**

+ Does not exceed 0.05 Tg CO_2 Eq.

Note: Totals may not sum due to independent rounding.

* "Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Table E-17: N_2O Emissions from Mobile Combustion (Tg CO_2 Eq.)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline Highway	**45.6**	**48.0**	**51.1**	**53.4**	**54.8**	**55.2**	**54.9**	**54.4**	**53.7**	**52.5**	**51.0**	**48.4**
Passenger Cars	30.9	30.7	31.8	32.5	33.3	33.4	33.0	32.5	32.2	31.2	30.2	28.6
Light-Duty Trucks	13.9	16.4	18.4	20.0	20.6	20.9	20.8	20.9	20.4	20.2	19.6	18.6
Heavy-Duty Vehicles	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.1
Motorcycles	+	+	+	+	+	+	+	+	+	+	+	+
Diesel Highway	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.6**	**2.6**	**2.8**	**2.9**	**3.0**	**3.0**	**3.1**
Passenger Cars	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	+	+	+
Light-Duty Trucks	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3

Heavy-Duty Vehicles	1.8	1.8	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7	2.7	2.8
Alternative Fuel Highway	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**
Non-Highway	**2.9**	**2.9**	**2.9**	**2.9**	**3.0**	**3.0**	**3.1**	**2.9**	**2.9**	**3.1**	**3.3**	**3.1**
Ships and Boats	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.4	0.5	0.3
Locomotives	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Agricultural Equipment	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Construction Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2
Aircraft	1.7	1.6	1.6	1.6	1.7	1.7	1.8	1.7	1.8	1.8	1.9	1.8
Other*	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Total	**50.6**	**53.0**	**56.2**	**58.6**	**60.4**	**60.9**	**60.7**	**60.3**	**59.7**	**58.8**	**57.5**	**54.8**

+ Does not exceed 0.05 Tg CO_2 Eq.

Note: Totals may not sum due to independent rounding.

* "Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Table E-18: NO_x Emissions from Mobile Combustion, 1990-2001 (Gg)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline Highway	**5,746**	**5,508**	**5,271**	**5,034**	**4,797**	**4,559**	**4,322**	**4,268**	**4,090**	**3,913**	**3,812**	**3,942**
Passenger Cars	3,847	3,628	3,409	3,190	2,971	2,752	2,533	2,447	2,316	2,152	2,084	2,150
Light-Duty Trucks	1,364	1,356	1,349	1,341	1,333	1,325	1,318	1,334	1,294	1,264	1,303	1,363
Heavy-Duty Vehicles	515	505	496	487	478	469	459	475	467	484	411	414
Motorcycles	20	19	17	16	15	14	13	13	13	13	13	14
Diesel Highway	**2,956**	**3,064**	**3,171**	**3,278**	**3,386**	**3,493**	**3,600**	**3,708**	**3,729**	**3,660**	**3,803**	**3,542**
Passenger Cars	39	35	31	27	23	19	15	13	11	10	7	6
Light-Duty Trucks	20	19	17	16	14	12	11	10	9	8	6	6
Heavy-Duty Vehicles	2,897	3,010	3,123	3,236	3,349	3,462	3,575	3,685	3,709	3,643	3,791	3,530
Alternative Fuel Highway	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Non-Highway	**3,432**	**3,492**	**3,552**	**3,612**	**3,672**	**3,732**	**3,791**	**3,792**	**3,772**	**4,009**	**3,780**	**3,770**
Ships and Boats	953	962	971	980	990	999	1,008	963	919	885	966	971
Locomotives	857	873	888	904	920	935	951	962	973	984	908	907
Agricultural Equipment	437	445	453	461	470	478	486	487	487	538	484	480
Construction Equipment	641	652	663	675	686	697	708	708	706	827	697	690
Aircraft[b]	63	64	65	65	66	67	67	75	83	91	80	73
Other[c]	480	496	511	526	541	556	572	597	604	683	645	650
Total	**12,134**	**12,064**	**11,994**	**11,924**	**11,854**	**11,784**	**11,714**	**11,768**	**11,592**	**11,582**	**11,395**	**11,254**

NE Not Estimated

[a] Aircraft estimates include only emissions related to LTO cycles, and therefore do not include cruise altitude emissions.

[b] "Other" includes gasoline powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel powered recreational, industrial, lawn and garden, light construction, airport service.

Note: Totals may not sum due to independent rounding.

Table E-19: CO Emissions from Mobile Combustion, 1990-2001 (Gg)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline Highway	**98,328**	**93,597**	**88,866**	**84,135**	**79,403**	**74,672**	**69,941**	**67,509**	**65,246**	**60,727**	**60,657**	**66,857**
Passenger Cars	60,757	57,019	53,281	49,542	45,804	42,065	38,327	36,825	35,686	32,661	32,867	37,250
Light-Duty Trucks	29,237	28,799	28,361	27,923	27,486	27,048	26,610	25,748	24,754	23,159	24,532	26,611
Heavy-Duty Vehicles	8,093	7,555	7,017	6,480	5,942	5,404	4,867	4,787	4,642	4,744	3,104	2,842
Motorcycles	240	223	206	189	172	155	138	150	163	163	154	155
Diesel Highway	**1,696**	**1,642**	**1,587**	**1,533**	**1,479**	**1,424**	**1,370**	**1,301**	**1,202**	**1,113**	**1,088**	**1,025**
Passenger Cars	35	31	28	25	21	18	15	13	10	10	7	7
Light-Duty Trucks	22	21	20	18	17	16	14	13	12	9	6	6
Heavy-Duty Vehicles	1,639	1,589	1,539	1,490	1,440	1,391	1,341	1,276	1,179	1,094	1,075	1,011
Alternative Fuel Highway	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Non-Highway	**19,459**	**19,899**	**20,339**	**20,778**	**21,218**	**21,658**	**22,098**	**21,474**	**21,493**	**22,733**	**21,935**	**22,387**

Ships and Boats	1,679	1,724	1,770	1,815	1,861	1,906	1,951	1,948	1,943	2,280	1,945	1,952
Locomotives	85	86	88	90	91	93	94	89	83	105	90	90
Agricultural Equipment	582	591	600	610	619	628	638	636	633	677	626	621
Construction Equipment	1,090	1,098	1,107	1,115	1,123	1,132	1,140	1,098	1,081	1,154	1,047	1,041
Aircraft[b]	217	218	220	221	222	224	225	250	274	307	245	233
Other[c]	15,807	16,181	16,554	16,928	17,302	17,676	18,049	17,453	17,478	18,210	17,981	18,449
Total	**119,482**	**115,137**	**110,791**	**106,446**	**102,100**	**97,755**	**93,409**	**90,284**	**87,940**	**84,574**	**83,680**	**90,268**

NE Not Estimated

[a] Aircraft estimates include only emissions related to LTO cycles, and therefore do not include cruise altitude emissions.

[b] "Other" includes gasoline powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel powered recreational, industrial, lawn and garden, light construction, airport service.

Note: Totals may not sum due to independent rounding.

Table E-20: NMVOCs Emissions from Mobile Combustion, 1990-2001 (Gg)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline Highway	**8,110**	**7,652**	**7,194**	**6,735**	**6,277**	**5,819**	**5,360**	**5,167**	**5,067**	**4,865**	**4,615**	**4,217**
Passenger Cars	5,120	4,774	4,429	4,084	3,739	3,394	3,049	2,928	2,895	2,777	2,610	2,355
Light-Duty Trucks	2,374	2,303	2,232	2,161	2,090	2,019	1,947	1,882	1,812	1,713	1,750	1,638
Heavy-Duty Vehicles	575	536	498	459	420	382	343	336	335	347	232	203
Motorcycles	42	38	35	31	28	24	21	22	25	27	23	22
Diesel Highway	**406**	**386**	**365**	**345**	**324**	**304**	**283**	**263**	**249**	**227**	**216**	**204**
Passenger Cars	16	15	13	12	10	8	7	6	5	5	3	3
Light-Duty Trucks	14	13	12	11	10	9	9	8	7	6	4	4
Heavy-Duty Vehicles	377	358	340	322	304	286	268	249	237	216	209	198
Alternative Fuel Highway	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Non-Highway	**2,416**	**2,457**	**2,498**	**2,540**	**2,581**	**2,622**	**2,663**	**2,498**	**2,427**	**2,567**	**2,398**	**2,379**
Ships and Boats	608	634	660	687	713	739	765	766	763	811	744	730
Locomotives	33	34	35	35	36	36	37	35	33	40	35	35
Agricultural Equipment	85	85	85	86	86	86	86	83	81	86	76	72
Construction Equipment	149	150	150	151	152	152	153	142	137	149	130	125
Aircraft[b]	28	28	28	28	28	28	28	32	35	40	24	19
Other[c]	1,513	1,527	1,540	1,553	1,567	1,580	1,593	1,441	1,378	1,442	1,390	1,397
Total	**10,933**	**10,495**	**10,058**	**9,620**	**9,182**	**8,744**	**8,306**	**7,928**	**7,742**	**7,658**	**7,230**	**6,800**

NE Not Estimated

[a] Aircraft estimates include only emissions related to LTO cycles, and therefore do not include cruise altitude emissions.

[b] "Other" includes gasoline powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel powered recreational, industrial, lawn and garden, light construction, airport service.

Note: Totals may not sum due to independent rounding.

Definitions of Emission Control Technologies and Standards

The N_2O and CH_4 emission factors used depend on the emission standards in place and the corresponding level of control technology for each vehicle type. Table E-9 through Table E-12 show the years in which these technologies or standards were in place and the penetration level for each vehicle type. These categories are defined below.

Uncontrolled

Vehicles manufactured prior to the implementation of pollution control technologies are designated as uncontrolled. Gasoline light-duty cars and trucks (pre-1973), gasoline heavy-duty vehicles (pre-1984), diesel vehicles (pre-1983), and motorcycles (pre-1996) are assumed to not have significant control technologies in place.

Gasoline Emission Controls

Below are the control technologies and emissions standards applicable to gasoline vehicles.

Non-catalyst

These emission controls were common in gasoline passenger cars and light-duty gasoline trucks during model years (1973-1974) but phased out thereafter, in heavy-duty gasoline vehicles beginning in the mid-1980s, and in motorcycles beginning in 1996. This technology reduces hydrocarbon (HC) and carbon monoxide (CO) emissions through adjustments to ignition timing and air-fuel ratio, air injection into the exhaust manifold, and exhaust gas recirculation (EGR) valves, which also helps meet vehicle NO_x standards (EPA 1994b).

Oxidation catalyst

This control technology designation represents the introduction of the catalytic converter, and was the most common technology in gasoline passenger cars and light-duty gasoline trucks made from 1975 to 1980 (cars) and 1975 to 1985 (trucks). This technology was also used in some heavy-duty gasoline vehicles between 1982 and the present. The two-way catalytic converter oxidizes HC and CO, significantly reducing emissions over 80 percent beyond non-catalyst-system capacity (EPA 1993). One reason unleaded gasoline was introduced in 1975 was due to the fact that oxidation catalysts cannot function properly with leaded gasoline (EPA 1994a).

EPA Tier 0

This emission standard from the Clean Air Act was met through the implementation of early "three-way" catalysts, therefore this technology was used in gasoline passenger cars and light-duty gasoline trucks sold beginning in the early 1980s, and remained common until 1994. This more sophisticated emission control system improves the efficiency of the catalyst by converting CO and HC to CO_2 and H_2O, reducing NO_x to nitrogen and oxygen, and using an on-board diagnostic computer and oxygen sensor (EPA 1994a). In addition, this type of catalyst includes a carburetor with electronic "trim" (also known as a "closed-loop carburetor") IPCC/UNEP/OECD/IEA (1997).[1] New cars with three-way catalysts met the Clean Air Act's amended standards (enacted in 1977) of reducing HC to 0.41 g/mile by 1980, CO to 3.4 g/mile by 1981 and NO_x to 1.0 g/mile by 1981.

EPA Tier 1

This emission standard created through the 1990 amendments to the Clean Air Act called for a 40 percent reduction from the 1981 standard. This was met through the use of more advanced 3-way catalysts, and applied to light-duty gasoline vehicles beginning in 1994. This catalyst includes electronically controlled fuel injections and ignition timing, EGR, and air injection. The EPA Tier 1 standards reduce NO_x emissions to 0.6 g/mile for cars and 0.6 to 1.53 g/mile for trucks (EPA 1999).

Low Emission Vehicles (LEV)

This emission standard provides the highest mobile emission control in effect currently at the national level. Applied to light-duty gasoline passenger cars and trucks beginning in small numbers in the mid-1990's, LEV includes multi-port fuel injection with adaptive learning, an advanced computer diagnostics systems and heated catalysts with secondary air injection IPCC/UNEP/OECD/IEA (1997). LEVs as defined here include transitional low-emission vehicles (TLEVs), low emission vehicles, ultra-low emission vehicles (ULEVs) and super ultra-low

[1] Electronic trim control systems change the ratio of fuel to air in the engine.

emission vehicles (SULEVs). In this analysis, all categories of LEVs are treated the same due to the fact that there are virtually no CH_4 or N_2O emission factor data for LEVs to distinguish among the different types of vehicles. Zero emission vehicles (ZEVs) are incorporated into the alternative fuel and advanced technology vehicle assessments.

Diesel Emission Controls

Below are the two levels of emissions control for diesel vehicles.

Moderate control

Improved injection timing technology and combustion system design for light- and heavy-duty diesel vehicles (generally in place in model years 1983 to 1995) are considered moderate control technologies (IPCC/UNEP/OECD/IEA 1997). These controls were implemented to meet emission standards for diesel trucks and buses adopted by the EPA in 1985 to be met in 1991 and 1994.

Advanced control

EGR and modern electronic control of the fuel injection system are designated as advanced control technologies. These technologies provide diesel vehicles with the current highest level of emission control, and were used in model years beginning in 1996.

Supplemental Information on Transportation-Related GHG Emissions

Although not required in greenhouse gas inventory reporting, IPCC allows presentation of further details and data. As the transportation end-use sector is a large consumer of fossil fuels in the United States, a more detailed disaggregation of transportation activities contributing to emissions is provided. Based on information and data sources that are already available, the supplemental data presented below are an effort to present this more detailed disaggregation.

Transportation-related sources include highway vehicles, aircraft, boats and ships, locomotives, and other transportation and mobile sources, as described in this annex. Transportation is typically defined as including pipelines (which are stationary), but not construction equipment, agricultural equipment, and certain other mobile sources that do not provide transportation *per se*[2]. Conversely, the term "mobile sources" does not include pipeline transportation, but does include construction equipment, agricultural equipment, and certain other mobile sources. Highway, rail, aviation, and waterborne vehicles all fall under both terms. This annex primarily uses the term transportation to include all transportation-related and mobile sources in this one category.

The estimates in Table E-21, Table E-22, and Table E-23 and illustrated in Figure E-1 were prepared by re-aggregating the estimates presented in Tables 1-14 and 2-7, Chapter 3, and Annex K so that each transportation mode and/or vehicle type is presented with its total greenhouse gas emissions, rather than its emissions disaggregated by fuel type or greenhouse gas. For the cases of Table E-1, Table E-23 and Figure E-1, DOE (1993 through 2002) and FHWA (1996 through 2002) were also used to allocate rail and heavy duty highway vehicle (trucks and buses) between freight and passenger categories. Otherwise, these tables and figures are dependent on the methodologies presented in Annex A (for CO_2), Chapter 3 and Annex K (for HFCs), and earlier in this Annex (for CH_4 and N_2O).

[2] Transportation is frequently defined in official surveys, etc. as the movement of persons or goods from one address to another address, and thus excludes many of the above-listed and other mobile sources.

The methodologies used to aggregate all the transportation greenhouse gas emissions data in Table E-21 are summarized here. The HFC emissions, which come from the coolants for air conditioning or refrigeration used in vehicles, are estimated, as indicated in Annex K, by calculating the number and types of coolant equipment in use and estimating the emissions from leakage during the equipment life and disposal. The CH_4 and N_2O emissions are estimated, as indicated in the fist part of this annex, by compiling the activity-level data and estimating emissions based on emission factors for each vehicle type. For non-road vehicles, the activity data is based on fuel consumption. However, for highway vehicles, an accurate estimate of methane and nitrous oxide emissions is dependent not just on the fuel consumption, but also on the type of vehicle and its associated criteria pollutant control technologies. Therefore, the methodology involves obtaining Vehicle Miles Traveled (VMT) data, assigning that activity by both fuel type and vehicle type, using the age distribution (and associated control technologies based on vehicle age) for the U.S. fleet. Then very specific emission factors can be used to estimate CH_4 and N_2O emissions based on the allocated activity level data. The CO_2 emissions are first estimated, as indicated in Annex A, by calculating fuel consumption for the transportation sector by fuel type and vehicle type, and estimating CO_2 emissions based on the carbon content of the fuel (see Table A-16 and Table A-17). However, identifying CO_2 emissions based on fuel type divides natural transportation categories such as passenger cars or buses into multiple line items (by listing emissions from gasoline separately from diesel or natural gas). The tables in this annex reorganize the CO_2 data according to the different modes of passenger vehicles, freight, and transit, and provide more detailed information on the activities that comprise these emissions. Table E-21 aggregates all greenhouse gases from transportation activities by mode.

Public Passenger Transportation

This section presents greenhouse gas emission estimates for "public passenger transportation", using a broad definition that includes all passenger vehicles available to the public for a fare or ticket price (or similar free services, such as many school buses or local shuttle buses). This category thus includes buses, passenger rail, and commercial aviation, as shown in Figure E-3. This category was developed to complement the previous two categories, passenger cars/trucks and freight, with the other main segment of the sector, public passenger transportation.

Uncertainty

Much of the data presented in this annex, such as the estimates from CO_2 emissions from transportation activities, are considered, in the aggregate, to be fairly accurate. Several of the tables in this annex represent the reorganization of data presented elsewhere in the Inventory, and this reorganization may introduce additional uncertainties in the disaggregated data. Minor uncertainty exists in the estimates of freight and public passenger transport emissions, where additional data from DOE (1993 through 2002) was used to allocate the passenger/freight split of rail emissions and to disaggregate buses. The data presented regarding daily travel, long-distance travel, and commodity flows all present the direct estimates made by their respective surveys. As the original surveys relied on survey and sampling techniques and attempted to collect detailed, disaggregate data, some uncertainty can be associated with their original estimates.

Table E-21: U.S. Greenhouse Gas Emissions from Transportation and Mobile Sources (Tg CO_2 Eq.)

Mode / Vehicle Type / Fuel Type	1990	1996	1997	1998	1999	2000	2001	Contribution to U.S. Transportation Total	Change from 1990-2001
Highway Vehicles	**1,172.0**	**1,318.8**	**1,340.7**	**1,375.9**	**1,419.7**	**1,435.5**	**1,456.3**	**77.9%**	**24.3%**
Passenger Cars	**633.9**	**629.6**	**627.5**	**642.4**	**652.0**	**654.0**	**663.6**	**35.5%**	**4.7%**
Gasoline	627.4	624.6	622.6	637.7	647.3	649.6	659.3	35.3%	5.1%
Diesel	6.4	4.8	4.7	4.5	4.4	4.2	4.0	0.2%	-37.9%
AFVs	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.0%	146.0%
Light-Duty Trucks	**322.4**	**429.8**	**442.4**	**450.3**	**468.4**	**472.0**	**480.7**	**25.7%**	**49.1%**
Gasoline	312.8	416.9	428.6	436.2	453.4	456.8	465.3	24.9%	48.8%
Diesel	9.1	12.4	13.4	13.6	14.7	14.8	15.0	0.8%	66.0%
AFVs	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.0%	-46.8%
Medium/Heavy-Duty Trucks	**206.5**	**249.3**	**260.5**	**272.5**	**287.4**	**297.8**	**301.3**	**16.1%**	**45.9%**
Gasoline	40.6	37.2	35.9	35.8	35.0	34.6	33.6	1.8%	-17.4%
Diesel	165.1	211.6	224.2	236.1	252.0	262.7	267.3	14.3%	62.0%
AFVs	0.8	0.5	0.4	0.6	0.5	0.5	0.5	0.0%	-40.9%
Buses	**7.5**	**8.3**	**8.5**	**8.8**	**9.9**	**9.8**	**9.0**	**0.5%**	**20.6%**
Gasoline	1.6	0.9	0.7	0.7	0.7	0.6	0.5	0.0%	-71.8%
Diesel	5.8	7.3	7.6	7.9	9.0	8.7	8.1	0.4%	39.3%
AFVs	0.0	0.1	0.2	0.3	0.3	0.5	0.4	0.0%	n.a.
Motorcycles	**1.8**	**1.8**	**1.8**	**1.8**	**1.9**	**1.9**	**1.7**	**0.1%**	**-3.7%**
Gasoline	1.8	1.8	1.8	1.8	1.9	1.9	1.7	0.1%	-3.7%
Aircraft	**178.8**	**182.1**	**180.9**	**185.0**	**188.7**	**197.4**	**185.9**	**9.9%**	**4.0%**
General Aviation Aircraft	**9.4**	**8.3**	**8.8**	**10.1**	**11.8**	**11.9**	**11.7**	**0.6%**	**25.1%**
Jet Fuel	6.3	5.8	6.1	7.7	9.2	9.5	9.3	0.5%	48.2%
Aviation Gasoline	3.1	2.6	2.7	2.4	2.7	2.5	2.4	0.1%	-22.3%
Commercial Aircraft	**120.0**	**126.8**	**131.3**	**133.4**	**139.2**	**143.0**	**133.5**	**7.1%**	**11.3%**
Jet Fuel	120.0	126.8	131.3	133.4	139.2	143.0	133.5	7.1%	11.3%
Military Aircraft	**34.8**	**23.1**	**21.0**	**21.5**	**20.6**	**21.0**	**22.8**	**1.2%**	**-34.3%**
Jet Fuel	34.8	23.1	21.0	21.5	20.6	21.0	22.8	1.2%	-34.3%
Other Aircraft	**14.6**	**23.9**	**19.7**	**19.9**	**17.0**	**21.4**	**17.8**	**1.0%**	**22.0%**
Jet Fuel	14.6	23.9	19.7	19.9	17.0	21.4	17.8	1.0%	22.0%
Boats and Ships	**49.0**	**48.6**	**34.0**	**27.7**	**39.1**	**60.3**	**58.7**	**3.1%**	**19.6%**
Gasoline	11.2	8.5	8.4	8.1	9.3	9.6	9.5	0.5%	-15.5%
Distillate Fuel	14.0	15.0	14.6	13.1	15.6	15.5	16.8	0.9%	20.0%
Residual Fuel	23.8	25.1	11.0	6.5	14.2	35.2	32.4	1.7%	35.9%
Locomotives	**28.4**	**32.2**	**32.0**	**32.7**	**34.4**	**34.2**	**34.6**	**1.9%**	**22.0%**
Distillate Fuel	27.8	31.6	31.3	32.1	33.8	33.4	33.9	1.8%	21.9%
Electricity	0.6	0.6	0.7	0.6	0.7	0.7	0.8	0.0%	28.2%
Pipelines	**38.3**	**41.1**	**43.3**	**37.3**	**37.8**	**37.7**	**36.3**	**1.9%**	**-5.4%**
Natural Gas	35.9	38.7	40.9	34.9	35.3	35.0	33.5	1.8%	-6.7%
Electricity	2.4	2.4	2.4	2.5	2.5	2.7	2.8	0.1%	14.6%
Agricultural Equipment	**33.4**	**34.5**	**34.6**	**32.3**	**29.7**	**31.5**	**35.5**	**1.9%**	**6.3%**
Gasoline	7.0	7.9	8.4	7.7	5.9	5.6	6.9	0.4%	-1.1%
Diesel	26.4	26.6	26.3	24.7	23.7	26.0	28.6	1.5%	8.2%
Construction Equipment	**16.0**	**16.0**	**16.3**	**16.6**	**16.1**	**17.7**	**22.2**	**1.2%**	**39.0%**
Gasoline	2.7	2.4	2.5	2.0	1.5	1.6	4.4	0.2%	59.8%

Diesel	13.2	13.6	13.8	14.6	14.6	16.0	17.8	1.0%	34.7%
Lubricants	11.7	10.9	11.5	12.0	12.1	12.0	12.1	0.6%	3.0%
Mobile Air Conditioners	**0.0**	**9.8**	**12.9**	**15.7**	**18.2**	**20.4**	**22.5**	**1.2%**	**NA**
Refrigerated Transport	**0.0**	**1.9**	**2.5**	**3.2**	**3.8**	**4.4**	**4.9**	**0.3%**	**NA**
Other*	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.0%**	**17.1%**
Total	**1,527.8**	**1,696.1**	**1,708.8**	**1,738.5**	**1,799.8**	**1,851.1**	**1,869.0**	**100.0%**	**22.3%**

* "Other" includes snowmobiles, small gasoline-powered utility equipment, heavy-duty gasoline-powered utility equipment, and heavy-duty diesel-powered utility equipment.
NA: Not Applicable
Source: Derived from Table 1-14, Table 2-7, Table E-16, and Table E-17. Greenhouse gas estimates for each mode were assigned to fuel types using fuel consumption data.
Note: For fuel types other than jet fuel, fuel consumption data by vehicle type and transportation mode were used to allocate emissions by fuel type calculated for the transportation end-use sector. The difference between total U.S. jet fuel consumption (as reported by EIA) and civilian air carrier consumption for both domestic and international flights (as reported by DOT and BEA) plus military jet fuel consumption is reported as "other" under the jet fuel category in Table 2-7, and includes such fuel uses as blending with heating oils and fuel used for chartered aircraft flights.

Figure E-1: 2001 Domestic Greenhouse Gas Emissions by Vehicle Type (Tg CO_2 Eq.)

*Other includes non-highway sources not in other categories, such as construction and agricultural equipment, pipelines, lubricants, mobile air conditioners, and refrigerated transport but does not include bunkers.
Source: Table E-21.

Table E-22: Greenhouse Gas Emissions from Domestic Freight Transportation (Tg CO_2 Eq.)

By Mode	1990	1996	1997	1998	1999	2000	2001	% Change 1990-2001
Trucking	206.5	249.3	260.5	272.5	287.4	297.8	301.3	46%
Rail	26.4	30.2	29.9	30.7	32.3	32.0	32.4	22%
Refrigerated Transport	0.0	1.9	2.5	3.2	3.8	4.4	4.9	NA
Waterborne	37.8	40.1	25.6	19.6	29.8	50.7	49.2	30%
Pipeline	38.3	41.1	43.3	37.3	37.8	37.7	36.3	-5%
Total	**309.1**	**362.7**	**361.9**	**363.3**	**391.1**	**422.6**	**424.0**	**37%**

NA Signifies data not applicable, as there were no HFC emissions allocated to the transport sector in 1990, and thus a growth rate cannot be calculated.
Note: Data from DOE (1993 through 2002) was used to allocate the passenger/freight split of rail emissions.

Figure E-2: Greenhouse Gas Emissions from Domestic Freight Transportation by Mode (Tg CO_2 Eq.)

Table E-23: Greenhouse Gas Emissions from Public Passenger Transportation (Tg CO_2 Eq.)

Vehicle Type / Fuel Type	1990	1996	1997	1998	1999	2000	2001
Passenger Rail	**2.0**	**1.9**	**2.1**	**2.1**	**2.1**	**2.2**	**2.3**
Electricity	0.6	0.6	0.7	0.6	0.7	0.7	0.8
Diesel	1.4	1.3	1.4	1.4	1.5	1.5	1.5
Buses	**7.5**	**8.3**	**8.5**	**8.8**	**9.9**	**9.8**	**9.0**
Gasoline	1.6	0.9	0.7	0.7	0.7	0.6	0.5
Diesel	5.8	7.3	7.6	7.9	9.0	8.7	8.1

AFVs	0.0	0.1	0.2	0.3	0.3	0.5	0.4
Commercial Aviation	**120.0**	**126.8**	**131.3**	**133.4**	**139.2**	**143.0**	**133.5**
Jet Fuel	120.0	126.8	131.3	133.4	139.2	143.0	133.5
Total	**128.1**	**135.7**	**140.5**	**142.9**	**149.8**	**153.5**	**143.3**

Source: Table 1-14.
Note: Data from DOE (1993 through 2002) was used to disaggregate emissions from rail and buses.

Figure E-3: Total Greenhouse Gas Emissions from Public Passenger Transportation by Vehicle Type (Tg CO_2 Eq.)

Figure E-1: 2001 Domestic GHG Emissions by Vehicle Type (Tg CO_2 Eq.)

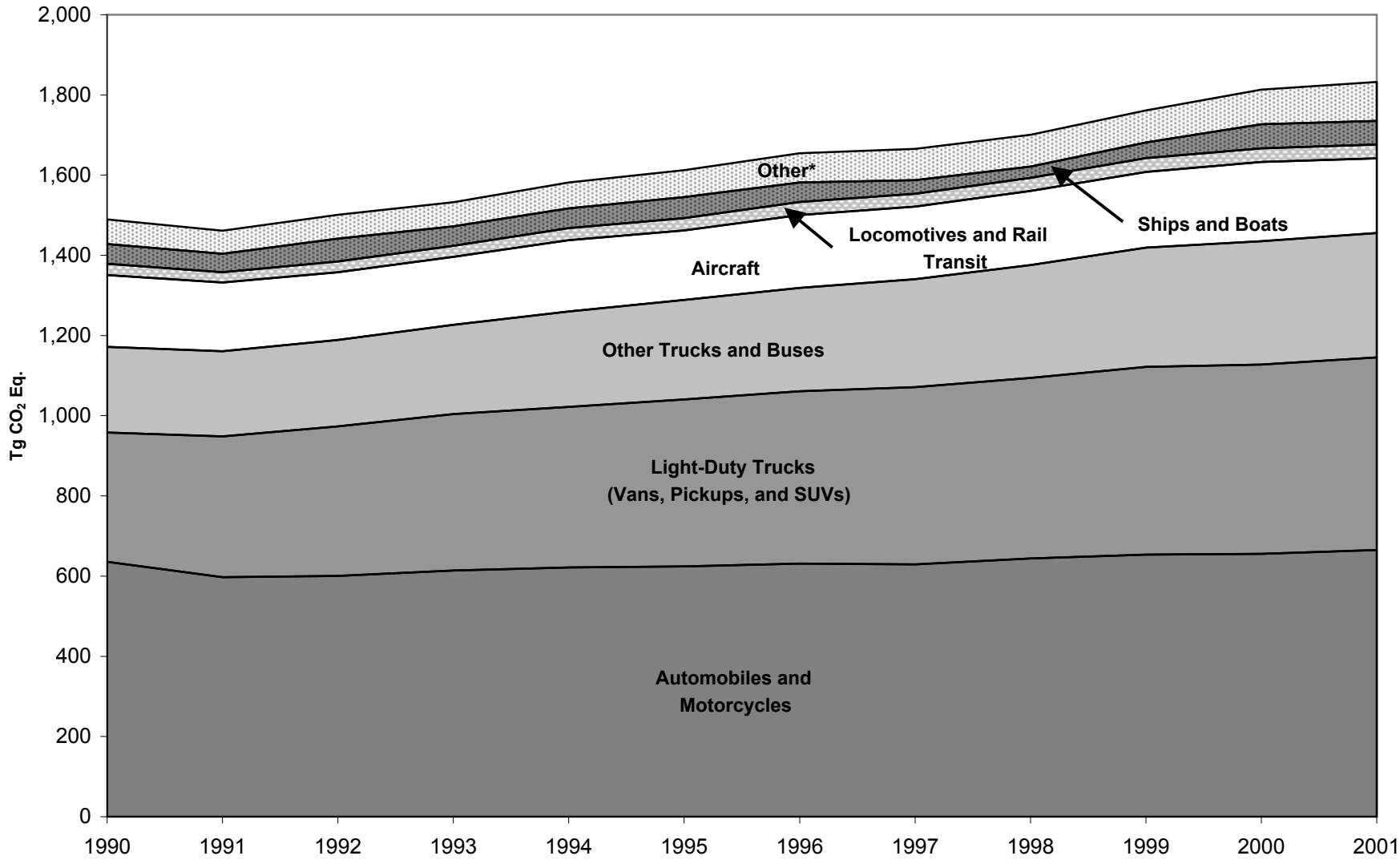

Figure E-2: Greenhouse Gas Emissions from Domestic Freight Transportation by Mode (Tg CO2 Eq.)

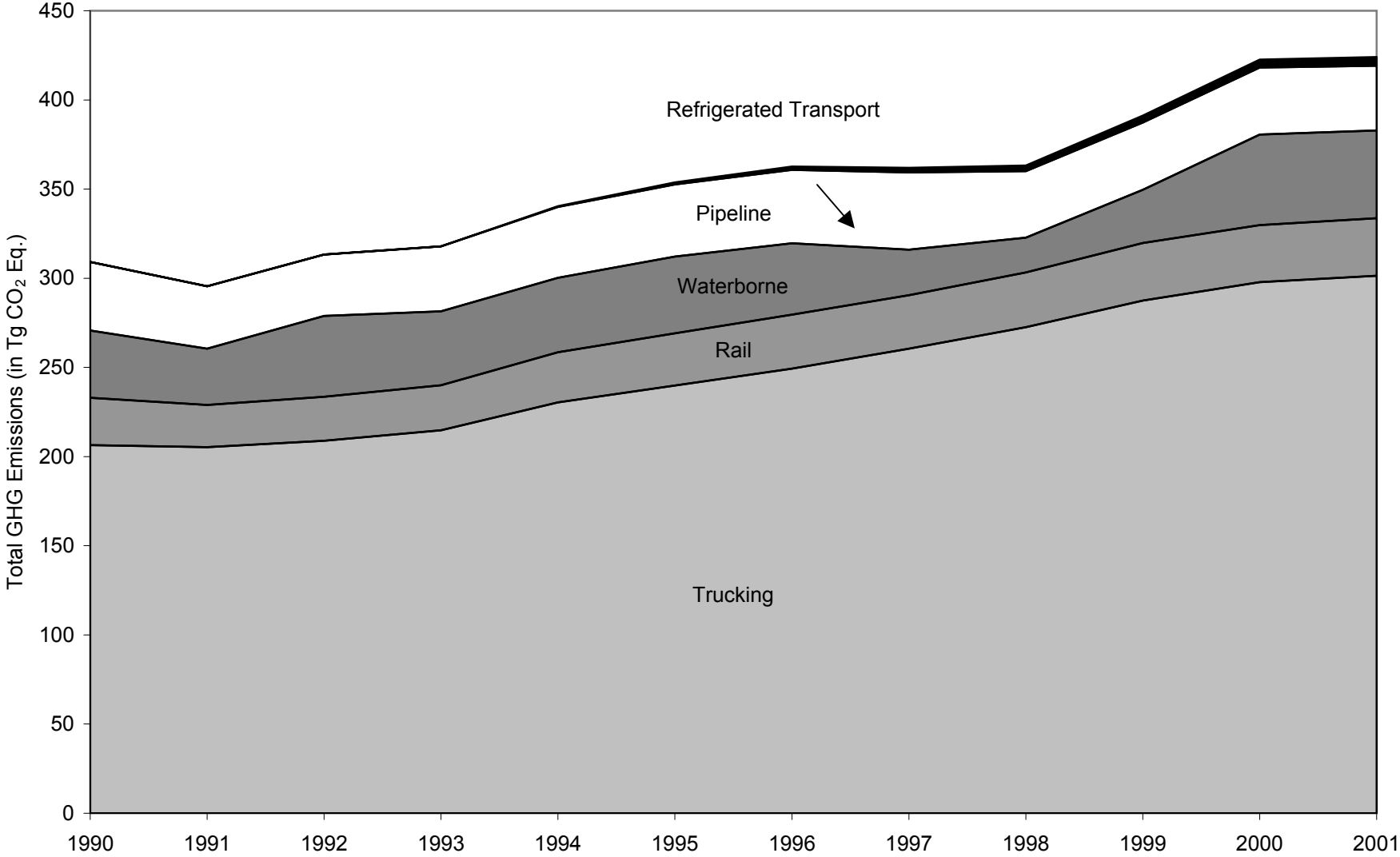

Figure E-3: Total Greenhouse Gas Emissions from Public Passenger Transportation by Vehicle Type (Tg CO2 Eq.)